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FIG. IV.—Same from above, the sculpture represented only on the first segment, enlarged fifty times.

FIG. V.—Same from the side, enlarged forty-eight times.

FIG. VI.—Tubercles on the upper surface of the segments near their junction, enlarged two hundred and fifty times.

FIG. VII.—Leg, enlarged fifty times.

FIG. VIII.—Spines and tubercles of the back, enlarged two hundred and fifty times.

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MICROSCOPICAL FUNGI INFESTING OUR CEREALS.[1]

BY WM. BARBECK.

I. Ergot.—In examining a rye-field about harvest time we may be pretty sure to find some plants in which, although the ears with their bracts or glumes are apparently developed in a normal way, some of the grains have attained an abnormal size and are of a somewhat blackish color. We have here what is generally known as "Ergot" (botanically *Claviceps purpurea* Tul.), a fungus which is to be found almost exclusively on rye, and which, because of its poisonous effects on animal organisms, is dreaded, particularly in those parts of Northern Europe where rye bread forms the staple daily food.

This fungus shows three distinct stages of development, two of which were well known to former botanists, but were described as separate species belonging to entirely different genera. It is to Tulasne that we owe the discovery of their immediate connection and succession.

Towards June, when the sexual parts have been differentiated, we see a mucous, honey-like substance flowing from out of the bracts of the ear. In examining this "honey-dew" (as it is called by farmers) under a microscope of high power, we behold it swarming with millions of minute oval spores, or conidia, which upon further examination we find to issue from a delicate but complicated mycelium which penetrates the ovary, gradually transforming it into a soft whitish body of an oblong shape with shriveled surface. In this form our fungus was described and recorded by Leveillé as *Spacelia segetum.*

In the course of a few weeks the gelatinous membranes of the mycelium-threads harden and assume a brownish color. Thus the originally soft tissue is transformed into a body of a corky or horny consistence. We now have the so-called " Ergot-grain," or the second stage of development of our fungus, formerly described as *Sclerotium clavus* Tode, and recognized as a good species among the Dermatomycetes. At the top of the " Ergot-grain " we behold the dried and shriveled remains of the *Spacelia* as a sort of hood of a dark-yellowish or brownish color.

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[1] Read before the Biological Section of the Academy of Natural Sciences, Philadelphia.

In this form of *Sclerotium*, the " Ergot-grains," most of which, of course, fall out of the ears when the corn is taken from the field, remain on the ground unchanged through the winter.

In April of the next year the third and very interesting form, which by its discoverer, Tulasne, has been termed *Claviceps purpurea*, is developed. We behold a number of purplish carpophores, each ending in a yellowish head growing out of the *Sclerotium*. Each of these little heads shows in longitudinal sections a row of regularly shaped and arranged *peridia*. These peridia are filled with a number of *asci* containing the very minute and thread-like spores. Direct experiments made by Prof. Kuehn, of Halle, and other mycologists, have proved beyond doubt that when these spores are sown into healthy young blossoms of rye, they will in a short time produce the mycelium of *Sphacelia*. The same result is sure to be obtained by means of the conidia of the honey-dew, which in a comparatively short time will infect other perfectly healthy ears, and will even carry the disease over to other surrounding plants, such as several species of grass, etc.

Thus we have to regard the *Claviceps* spores as originating the disease in spring; the *Sphacelia* as propagating it during the period of fructification, and the *Sclerotium* as preserving the contagion through the winter.

It is generally known that the ergot when brought into the human organism operates as a narcotic poison. In certain years which were particularly favorable to its development, numerous cases of poisoning have been observed in Europe, and so we learn of a series of ergot epidemics recorded in official European statistics. In 1771, for instance, the disease was so acute in Westphalia and Hanover that in certain villages more than ninety per cent. of the cases proved fatal.

The parasite has acquired its German name " Mutterkorn," because of its contracting effects upon the uterus, owing to which it has become an efficient aid in obstetrics, well known under the old name of *Secale cornutum*.

The ergot in its *Sphacelia* form is, as mentioned before, not confined exclusively to rye, but its conidia infect several species of grass, such as Lolium, Bromus, Dactylis and others. Thus a number of diseases befalling our domestic animals are most probably to be ascribed to the "honey-dew" which the animals have eaten with such infected grasses. Of course the farmer ought to remove the infected plants growing in the neighborhood of his rye fields. He ought to pick out the ergot grains as much as possible before the corn is mown, and as they are only formed during the short period of fructification, he has to apply such methods of cultivating his ground (particularly the drilling) as tend to produce a simultaneous development of the fruits, thus reducing the dangerous period to a comparatively short time.

II. Smuts.—The Ustilagineæ, or smuts, are parasitic fungi whose fine-threaded, wide-spreading mycelium grows through large portions of the infected plants. They fructify, however, only in certain parts of these plants and at certain periods. In such proper places the threads of the mycelium increase rapidly, resorbing the surrounding tissue. Their free ends become divided into cells; the latter, after being separated, are surrounded by a second membrane and thus transformed into spores. These spores occupy as a brownish dust or powder the place of the destroyed tissue, and are set free in a measure as the infected parts decay.

The organs of the plant in which these fungi are fructifying, vary according to the species of smut. So we see the whole panicle of oat infected by *Ustilago carbo*, or "*oat-smut*;" the interior of the wheat grains by *Tilletia caries*, or "*bunt*;" the anthers of several *Sileneæ* by *Ustilago antherarum*, and the female cobs of our maize by *Ustilago maydis*, or *maize-smut*. When in any of these Ustilagineæ the spores are being formed, the threads of the mycelium become dissolved and disappear; consequently when the smut is fully developed we shall find nothing but the afore-mentioned spores.

Numerous experiments have shown that these spores maintain their power of germination for several years. When brought on a moist substratum they produce, within a few days, a germ tube or promycelium on which minute sporidia of various shapes, according to the various species of smut, are formed. According to the observations of Hoffmann, Kühn and other eminent botanists, these sporidia penetrate the epidermis of young and tender corn-stalks, mostly in the region between the root and the first joint of the stem. The mycelium grows in an upward direction, following the course of the longitudinal cells. However, the growth of the plant seems not to be injured; on the contrary, the infected plants are apparently of a more fresh and bluish green, and it is not before the time of fructification that the devastation becomes visible.

The process of germinating is very nearly the same in the oat and maize smut, whereas the "bunt," or *Tilletia caries* shows some interesting peculiarities. In this parasite, which is to be found exclusively within wheat grains, the sporidia are produced in a verticillate manner from the germ tube. They repeatedly anastomose, and this anastomosis, or conjunction, is considered as an act of fructification, for immediately afterwards we see that oöspores are formed, from which very minute threads are sent forth which become free and carry the disease over to other wheat plants.

It requires an experienced eye to discover the bunt in any wheat field, for the infected ears are not distinguished in their outer appearance from the healthy ones. The diseased grains, however, when rubbed between the fingers, burst at the slightest pressure, and we see that instead of the white meal they are filled with a dark smutty mass, which is distinguished by a nauseous smell resembling herring brine, produced by a volatile oil, the trimethylamine, which is also to be found in herrings.

However destructive all these smuts may be, it is within the power of any farmer, if not to prevent at least to limit their excessive increase. The spores have been found adhering in large numbers to the grains which are harvested, and which, of course, when sown in spring, will transmit the contagion to the next crop. Now a solution of copper-vitriol, which is not hurtful to the seeds, is sure to kill the dangerous spores, and so we have an efficacious and at the same time cheap preventive remedy on hand.

III. Rusts and Brands.—The parasites of the hitherto described species we have found to be destructive to the several organs of fructification. The following fungi belong to an entirely different genus. They infest and destroy the stem as well as the leaves and vaginæ of our gramineæ and other cultivated plants, and are generally known under the name of rusts and brands, or *Uredineæ.*

In examining our corn-fields in the beginning of summer we shall most likely find a number of plants covered all over with bright rusty, later in the year with dark brownish spots and lines. These pustules are produced by parasitic fungi which have their seat under the epidermis of the infected plants, and after being developed, burst through the epidermis in order to disseminate their spores. The very interesting development of these Uredineæ is a comparatively recent discovery, the more interesting as the originators of the disease are to be found on plants belonging to families entirely different from those in which the parasites are developed.

If in May or June we examine the leaves of some *Berberideæ*, *Rhamnaceæ* or *Asperifoliaceæ* growing in the neighborhood of our corn-fields (particularly those in damp localities), we may be pretty sure to find the under surface of such leaves covered all over with little cup- or jar-like bodies of a bright-rusty color. These little cups are what have long since been known as cluster-cups, or *Æcidium.* They present an elegant object under the microscope, and delicate sections will show that the interior of the cups is crowded with basidia, from which regular rows of bright-colored spores proceed. (These cluster-cups are generally attended by numbers of those strange little bodies known as spermogonia, growing mostly from out of the opposite side of the leaf, and sending forth thread-like spermatia, the real nature of which has as yet not been ascertained.)

Prof. de Bary, of Strasburg, has been the first to show that when these *Æcidium* spores are brought on certain species of corn, for instance those of *Berberis*, or Barberry, on rye, they immediately begin to germinate. The tender germ tubes force their way through the stomata and rapidly develop within the infected leaf a mycelium from which the afore-mentioned spores are produced on basidia beneath the epidermis. Prof. de Bary was led to the investigation by the pertinacious and often ridiculed assertion of old farmers, that the shrubs of Barberry were injurious to rye and oats; and indeed, his repeated direct experiments, as well as those of a number of other botanists, have proved beyond doubt that a very dangerous form of rust, the *Uredo linearis*, is produced only by the spores of Barberry cluster-cups.

In the same way it has been shown that other rust diseases, for instance, such as are produced by *Uredo rubigo vera*, which also destroys our cereal plants, are originated by certain cluster-cups growing on other plants in the neighborhood of corn-fields.

If we examine the rust-pustules more closely, either by opening them with a needle or by making thin sections, we shall find beneath the epidermis and growing on short peduncles, numerous yellowish spores. They represent simple oval cells, the protoplasm of which contains little drops of an orange-colored oil. The hyaline episporium is granulated and shows several translucent spots, the places from which the germ tubes will proceed. These germ tubes are rapidly developed, often within a few hours. They penetrate the stomata of other leaves and repeat the production, first of a mycelium, then of numerous spores, which again pierce with their germs through the epidermis of other plants. In this way the the process is continued through the course of summer, and it is easily explainable that under favorable circumstances the disease may be propagated from field to field, over vast tracts of land, assuming quite an epidemic character.

Towards the close of the hot season we see our fungi entering a new stage of their development. Repeated examinations of the rusty pustules will show that the latter are gradually transformed into bodies of a dark-brownish color. Let us examine these dark bodies a little closer. We shall find that from the former mycelium spores of a quite different shape and color have been produced. The Uredo or summer spores have disappeared and in their place we behold numerous dark-brownish two-celled spores with thick or perfectly smooth membranes growing on long pedicles. They are what is known as *brand* (*Puccinia*), and were formerly described as an autonomous species of fungi. In reality they are the winter or Teleuto spores of the rust. The spores remain with their peduncles attached to their stroma during the winter, and do not begin their germination before the following spring. Then one or several germ tubes are formed, which at their upper extremities become segmented into several cells. From each of these cells we see growing out a very fine thread, producing a sporidium. These sporidia are set free and are scattered by the wind, and when brought on the leaves of barberry are sure to produce the cluster-cups first described. (The latter fact has again been proved by numerous direct experiments.)

Thus we see the *Æcidium* producing *Uredo*, the *Uredo Puccinia*, and the *Puccinia* again *Æcidium*, and we have the interesting fact, that fungi of an apparently unlike structure, which have been hitherto described as belonging to different genera, and which are actually to be found on entirely different plants, are in reality but sucessive forms of development of the same parasite.

By this discovery of De Bary, the attention of a number of mycologists was directed to other species of rusts. Numerous experiments have been made, and thus the connection of a number of hitherto separated forms has been found out. We know, for instance, that one species of Uredo, *U. straminis*, which destroys the glumes and attacks the ovaries of wheat-ears, and which in 1862, in Denmark, caused a damage of nearly a million of dollars, has its *Æcidium* form on the several *Boragineæ*; that a disease on pear trees, destructive to the young leaves and ovaries, and known as *Rœstelia cancellata*, is the *Æcidium* form of a *Uredo* growing in early spring on *Juniperus* and hitherto described as *Gymnosporangium*.

In some rusts the winter spores present a form at the same time very elegant and quite different from *Puccinia*. So we see towards autumn the under surface of blackberry and rose leaves spotted all over with little blackish powdery tufts of the so-called blackberry brand or *Phragmidium*. These tufts are composed of four or five-celled elegantly granulated spores, produced on long hyaline peduncles. In the same places where we find them now we would have met a month ago the one-celled Uredo spores, and it is quite interesting to observe under a lens from day to day how (beginning at the circumference and moving towards the center) the dark winter spores are gradually superseding those of Uredo. This connection has also been discovered but recently.

In the same way the dimorphism of several other rusts and brands has been defined. However, we are as yet ignorant as to the development of a good many other species, and there is consequently a vast and at the same time highly interesting field left for further investigation.

IV. Mildew.—"Mildew," says M. C. Cooke in his Parasitic Fungi, "is one of those loose terms which represent no definite idea, or a different one to different individuals." It may be so in England; American farmers, however, as well as horticulturists of my acquaintance, unanimously apply the term to the several species of *Erysiphe*, and so I understand under the name of " mildew " the mycelium of a parasitic fungus which, sometimes very thin and cobweb-like, sometimes in a thick, felty layer, disturbs the development of the infected plant, particularly by obstructing the stomata, perhaps also by drawing its nourishment from out of the infected organs by means of little wart-like processes, through which the mycelium is attached to the plant on which it feeds.

Among the great many varieties of *Erysiphe*, which are to be found on the leaves of different trees as well as on a great many ornamental and useful plants, we have to deal here with one species, *E. graminis*, which in certain years is to be found in abundance, covering the leaves of the several cereals.

The real nature of this parasite has likewise but recently been discovered, and it requires a good microscope to discern the minute organs of fructification.

Soon after the formation of the " mildew " has commenced, we see some of the mycelium-threads growing upwards in a vertical direction. These threads become segmented into several cells ; each of these oval cells is separated in the same way as we have seen in Sphacelia, is transformed into a conidium, and by means of these conidia, the mycelium is propagated during the summer months, with incredible rapidity under favorable conditions.

Towards the close of the period of the growth of vegetation we see in a very interesting way that peridia are formed by means of a sexual process.

At the crossing point of two mycelium-threads two cells of a somewhat unlike shape are differentiated. The larger one, issuing from the inferior hypha, is club-shaped. It is (according to De Bary, to whom we are indebted for very careful investigations of this subject) the female "ascogonium," as he terms it, against which the much thinner "pollinarium" (growing up from the inferior hypha) leans closely. The contents of the pollinarium being absorbed by the female organ, the latter begins to swell or enlarge as the pollinarium disappears. In the mean time a number of secondary threads are developed at the basis of the ascogonium. These threads surround and enclose the ascogonium, producing numerous lateral as well as inward growing ramifications. The lateral threads weave themselves into a compact tissue which afterwards hardens, becomes brownish and forms the outer coat of a peridium, while the space between this coat and the ascogonium is filled up by the loose tissue of the inner ramifications.

The ascogonium is divided by repeated partition into a number of asci, each of which in our species contains eight spores. According to the observations of several botanists, these spores are not developed before the next spring, so that the parasite is preserved through the winter by means of the peridia. In most species of *Erysiphe* these peridia are provided with hyaline appendages, some of which are of wonderful regularity and elegance of form, when seen under the microscope.

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FRESH-WATER ENTOMOSTRACA.

BY C. L. HERRICK.

THE collector of fresh-water specimens is constantly meeting unexpected forms, especially among the smaller organisms, and of these no order of animals furnishes a wider variety or more curious adaptations than the fresh-water Crustaceans embraced in the old group *Entomostraca*, which is by many authors at the present day subdivided into several orders of Crustacea, the name being retained for a single order. To the microscopist particularly they are available as a never-failing field for study, since a cup of water from almost any source will contain abundant material for a day's work.

The Entomostraca have specialized jaws, but the gnathites never exceed three pairs. The segments of the abdomen are devoid of appendages. The name was derived from two words, meaning insect and shell, by Otho F. Müller, and applied by him in his "Entomostraca" (1785) to the animals which had hitherto been all comprised in Linnæus' genus *Monoculus*, named from the supposition that they possess but one eye. This order has, generally speaking, been much neglected, and in America particularly it seems to have escaped attention. The members of this order are never large, and many are so small as to be with the greatest difficulty detected by the unassisted eye, yet from their great variety, wide range and immense number they assume a position of considerable importance in the animal kingdom.

Recent investigations instituted by Mr. S. A. Forbes, of the Illinois State Laboratory of Natural History, have emphasized the fact that the lowly animals play important parts in the economy of nature, he having found that these Crustaceans enter